

# A GRB Detection System using the BGO-Shield of the INTEGRAL-Spectrometer SPI

Andreas von Kienlin, Nikolas Arend, and Giselher G. Lichti

Max-Planck-Institut für extraterrestrische Physik, 85741 Garching, Germany

**Abstract.** The anticoincidence shield (ACS) of the INTEGRAL-spectrometer SPI consists of 512 kg of BGO crystals. This massive scintillator allows the measurement of gamma-ray bursts (GRBs) with a very high sensitivity. Estimations have shown that with the ACS some hundred gamma-ray bursts per year on the  $5\sigma$  level can be detected, having an equivalent sensitivity to BATSE. The GRB detection will be part of the real-time INTEGRAL burst-alert system (IBAS). The ACS branch of IBAS will produce burst alerts and light curves with 50 ms resolution. It is planned to use ACS burst alerts in the 4th interplanetary network (IPN) [1].

## 1 The Anticoincidence Shield of SPI

The spectrometer SPI [2] is one of the two main instruments on INTEGRAL, one of ESA's next missions devoted to  $\gamma$ -ray research. Fig. 1 shows a drawing of the spectrometer SPI. The camera of SPI, which consists of 19 cooled high-purity germanium detectors, is shielded on the side walls and rear side by a large anticoincidence shield (ACS). The field of view of the camera is defined by the upper opening of the ACS. The imaging capability of the instrument is attained by a passive-coded mask on the top. Below the mask a plasticscintillator anticoincidence (PSAC) takes care for the reduction of the 511 keV background, which is mainly generated by particle interactions in the mask.

The ACS consists of 91 BGO crystals which are arranged in 4 subunits. The units of the upper veto shield (UVS) consists of the upper collimator ring (UCR), the lower collimator ring (LCR) and the side shield assembly (SSA), each containing 18 crystals which are arranged hexagonally around the cylindrical axis of SPI. The lower veto shield (LVS), consisting of 36 crystals, is assembled as a hexagonal shell. The thickness of the crystals increases from 16 mm at the top (UCR) to 50 mm at the bottom (LVS). The total mass of BGO used for the ACS is 512 kg resulting in the obvious use of the ACS as a burst monitor.

Each BGO crystal of the ACS (with one exception) is viewed by two photomultipliers (PMTs). Due to the redundancy concept used for the ACS, each of the 91 front-end electronic boxes (FEEs) sums the anode signals of two PMTs, which are viewing different BGO crystals (in most cases neighbouring crystals). This cross strapping of FEEs and BGO units leads in a failure case of one single PMT or FEE not to the loss of a complete BGO crystal. It emerges that a disadvantage of this method is an uncertainty in the energy-threshold value of individual FEEs, caused by a different light yield of neighbouring BGO-crystals and different PMT properties like quantum efficiency and amplification. A result

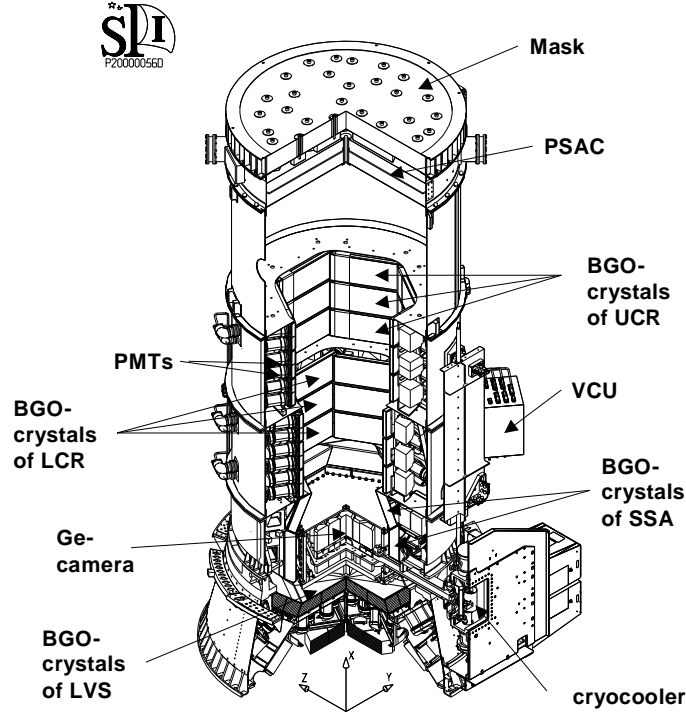
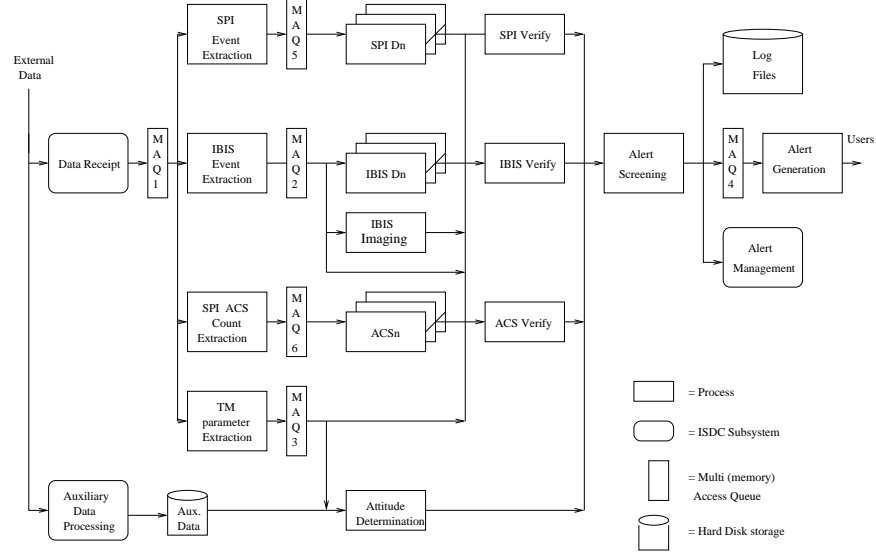


Fig. 1. INTEGRAL Spectrometer SPI

of this is that the threshold extends over a wide energy range and is not at all sharp. The energy-threshold settings of the ACS depend on a tradeoff between background reduction and deadtime for the SPI camera.

## 2 The ACS as GRB Monitor

The main task of the ACS as a detector is the veto generation for charged particles and  $\gamma$ -rays coming from outside the FoV. But there are also data which can be used for scientific purposes. The ACS housekeeping (HK) data include the values of the overall veto counter of the veto control unit (VCU) and the individual ratemeter values of each FEE. Both HK data are suitable for burst detection. The count rate of the overall veto counter (ORed veto signals of all 91 FEEs) is sampled every 50 ms. A packet, containing 160 consecutive count rates, will be transmitted every 8 sec to ground. If no gap in the telemetry stream occurs one could have a continuous ACS veto-rate light curve with 50 ms binning. The measurement time of the individual FEE ratemeter can be adjusted between 0.1 and 2 sec. All 91 FEEs are read out successively in groups of 8 FEEs every 8 sec. The read out of all 91 ratemeter values thus needs 96 sec. In distinction



**Fig. 2.** IBAS structure

to the VCU overall veto counter the individual ratemeter values do not yield a continuous stream. Additionally the values of different FEE groups are shifted by a time interval of 8 sec. So it is very difficult to derive the burst-arrival direction from these individual counting rates.

### 3 SPI/ACS Burst-Alert System

The search for GRBs in the ACS veto-rate light curve and the generation of alerts will be performed automatically on ground at the INTEGRAL Science Data Center (ISDC). The ISDC system responsible for the monitoring of the data for burst occurrence of all INTEGRAL instruments is the INTEGRAL Burst Alert System (IBAS) [3]. The structure of IBAS is shown in Fig.2. The SPI/ACS Burst Alert System (SACS-BAS) is one branch of IBAS. The telemetry (TM) files of the INTEGRAL satellite are transmitted via the Mission Operation Center (MOC) to the ISDC and are then directly fed into the real-time telemetry (RTTM) receiver of the IBAS system. After distribution and extraction of the relevant data, each IBAS branch is processing a burst-search algorithm with a subsequent verify procedure. The trigger algorithm used for SACS-BAS is looking for a significant excess with respect to a running average, comparable to the trigger algorithm used for other spacecrafts (e.g. ULYSSES). Due to the sufficient computing power available on ground it is possible to run several burst-search and burst-verify processes in parallel. SACS-BAS has also implemented this option: several trigger processes with different time bin durations will run in parallel in order to be able to trigger on bursts with different temporal behaviour; several

verify processes with different criteria, gain for the suppression of fault triggers generated by background variations, could be started in SACS-BAS after a burst alert. Up to now SACS-BAS is only reading the overall-veto counter values. But it is planned also to include the read out of rate meter-values of individual FEEs into the SACS-BAS routine. This will allow a rough estimation of the GRB arrival direction. An accuracy of about  $10^\circ$  -  $20^\circ$  will be enough to distinguish between the two arrival-cone intersections of the interplanetary network (IPN). The SACS-BAS trigger algorithm will be tested with generated TM data of simulated burst data plus background. After launch all parameters for the trigger algorithm and verify criteria will be optimised.

The output of SACS-BAS will be burst alerts, containing information about the trigger time in universal time (UT), the spacecraft position and its attitude. The alerts will be transmitted to subscribed users by e-mail and/or direct TCP/IP socket. Especially for the IPN the burst time history ( $\sim 100$  s) is important for the alignment of the light curves obtained from different spacecrafts. For this purpose the time history together with the pre-trigger time-history ( $\sim 5$  s) will be transmitted to the IPN. It is important for the IPN to know the burst arrival time with a millisecond accuracy. As already shown in [4] this is possible for the ACS overall counter values.

## 4 Sensitivity Estimation

An estimation of the expected rate of GRBs detected by ACS has already been given in [4]. For an effective area of about  $3000 \text{ cm}^2$ , an ACS background rate between  $\sim 80000 \text{ cts/s}$  and  $\sim 160000 \text{ cts/s}$ , an ACS threshold of 80 keV and a time binning of 50 ms the minimal detectable energy flux lies between  $2 \leftrightarrow 2.8 \times 10^{-6} \frac{\text{erg}}{\text{cm}^2 \text{sec}}$ . For a time binning of 1 sec the sensitivity increases to  $5 \times 10^{-7} \frac{\text{erg}}{\text{cm}^2 \text{sec}}$ . Using the logN-logP distribution, measured by BATSE and PVO [5] one can derive the number of bursts which will be observed with the ACS in one year. The resulting values are  $\sim 50$  bursts/year for 50 ms integration time and  $\sim 280$  bursts/year for 1 sec integration time. The response of ACS depends on the infalling direction of a burst due to projection effects of other ACS crystals and due to shielding of neighbouring instruments and spacecraft structure. The burst intensity could be determined once the infalling direction is known. This is possible only via Monte-Carlo simulations using the INTEGRAL mass model. Similar simulations have been performed by P. Jean et al. [6] in order to determine the sensitivity of the ACS for detection of novae.

## References

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